American

POTATO JOURNAL

Volume 33 **September 1956** **Number 9**

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NEWS AND REVIEWS

Official Publication of

THE POTATO ASSOCIATION OF AMERICA

NEW BRUNSWICK, NEW JERSEY, U. S. A.

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PUBLISHED BY
THE POTATO ASSOCIATION OF AMERICA
NEW BRUNSWICK, N. J.

Price $4.00 per year in North America; $5.00 in other countries.

Entered as second class matter at New Brunswick, N. J., March 14, 1942 under Act of March 3, 1879. Accepted for mailing at special rate of postage provided for in section 412, Act of February 28, 1925, authorized on March 14, 1928.

EFFECTS OF SOME METABOLIC INHIBITORS ON SUGAR ACCUMULATION IN POTATO DISCS DURING PARTIAL DESICCATION[1]

C. C. Craft[2]

Potato tubers accumulate sugars during low- (31°-50° F.) and high-temperature (85°-100° F.) storage. Potato tissue accumulates sugars during partial desiccation. The first sugar to accumulate is sucrose (5, 6) and starch is known to be the source. Temperatures between 32° and 104 have little effect on the final amount of starch converted to sucrose during partial desiccation of potato tissue, but each rise of 18° F. (10° C.) accelerates the velocity of accumulation about 1.5 times. Rapid drying may cause potato tissue to reach a critical moisture content that will stop the reaction before there is any appreciable starch-sugar interconversion (6). Sucrose accumulation in potato tissue does not occur in the absence of oxygen (4) or after death of the tissue.

Since frost, drought (*i.e.* desiccation), and heat resistance in plants are now considered basically similar (3), it is probable that the accumulations of sugars by potato tissue at low and high temperatures and during partial desiccation have similar physiological bases. The purpose of the present study of sugar accumulation in potato tissue during partial desiccation was to determine whether sugar accumulation in potato tubers can be prevented.

Materials and Methods

The work reported here was done on late-crop potatoes of the varieties Russet Burbank and Katahdin during three seasons. The potatoes were placed in storage at 55° F. and used from time to time during the winter. Cylinders of tissue 1.5 cm. in diameter were cut with a cork-borer and sliced into discs 1 to 2 cm. thick. The discs were washed in running tap water for several hours and blotted dry before weighing. Slow desiccation was accomplished by placing the discs in open dishes in a large incubator oven at 70°. Rapid desiccation was accomplished by placing them in a stream of air.

The discs were treated with the different metabolic inhibitors by immersion for a 2-hour period or by vacuum-infiltration for approximately 20 minutes with the different solutions. Both methods appeared satisfactory. After treatment the discs were blotted dry and partially desiccated along with the appropriate control samples.

Reducing and total sugars were determined by th Shaffer-Somogyi method as modified by Heinze and Murneek (1). Sucrose was calculated as the difference.

At the ends of the periods of desiccation the rates of respiration of the potato discs were determined by conventional Warburg methods at 70° F. in vessels of 125-ml. capacity without the addition of fluid.

Results

Little or no sugar accumulated and no change in the alcohol-insoluble

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solids was detectable in potato discs partially desiccated in the absence of oxygen (Table 1). From this it would appear that there is a metabolic step between starch and sucrose that requires oxygen and that the blocking of this step prevents starch hydrolysis. Sugar accumulation during partial desiccation, however, was only partially inhibited when the levels of oxygen were between 1 and 2 per cent.

During rapid desiccation of the potato discs to below 50 per cent of their original fresh weight there was an accumulation of sucrose but no accumulation of reducing sugars (Table 2). The amount of sucrose accumulated was less than when the fresh weight was reduced at a slower rate. During slow desiccation reducing sugars also accumulated. These results indicate that reactions requiring a finite time are involved either in sucrose synthesis or in the development of the physiological conditions leading to sucrose accumulation. During rapid desiccation sucrose accumulation is apparently stopped by a critical water content before the concentration attains the equilibrium range found during slow desiccation.

Potato discs treated with metabolic inhibitors and partially desiccated also accumulated sugars (Table 3). Sucrose and total sugars were significantly greater in discs given the NaF treatment than in the water-

TABLE 1.—*Sugars and alcohol-insoluble solids in Russet Burbank potato discs partially desiccated at room temperature for 48 hours in atmospheres containing different concentrations of oxygen.*[1]

Disc Treatment	Weight Loss	Reducing Sugars	Sucrose	Alcohol-insoluble Solids
	Per cent	Per cent	Per cent	Per cent
None (original discs)	—	0.12	0.08	17.4
Drying in Air	23	.82	1.12	15.1
Drying in N_2	18	.18	.32	16.9
Drying in Vacuum	19	.10	.12	17.6
Drying in 1-2 per cent O_2	18	0.27	0.74	16.3

[1] Means of 3 replications calculated as per cent of original fresh weight.

TABLE 2.—*Sugars in Katahdin potato discs partially desiccated at different rates at room temperature.*[1]

Hours of Drying	Weight Loss	Reducing Sugars	Sucrose
	Per cent	Per cent	Per cent
0	—	0.12	0.07
8	7	.18	.10
8	63	.07	.58
24	5	.36	.17
24	55	.16	.94
72	18	0.73	0.97

[1] Means of 3 replications calculated as per cent of original fresh weight.

infiltrated control discs subjected to similar partial desiccation. Similarly, in the 2,4-dinitrophenol (DNP) treatment sucrose and total sugars were significantly greater, but reducing sugars were significantly less than in the water-infiltrated control treatment.

When potato discs were infiltrated with 10^{-3} M DNP, pH 5.0, and partially desiccated, no sugars accumulated and the tissue was killed (Table 4). In discs infiltrated with 5 x 10^{-4} M and 10^{-4} M DNP, pH 5.0, and partially desiccated only a part of the cells were killed and small amounts of sucrose but no reducing sugars accumulated. In discs infiltrated with 5 x 10^{-5} and 10^{-5} M DNP, pH 5.0, the accumulated reducing sugars were less than in the water-infiltrated control discs

TABLE 3.—*Sugars in and appearance of Russet Burbank potato discs infiltrated and not infiltrated with certain metabolic inhibitors and partially desiccated for 68 hours at 70° F.*[1]

Disc Treatment	Appearance after 68 Hours	Weight Loss	Reducing Sugars	Sucrose	Total Sugars
		Per cent	Per cent	Per cent	Per cent
None (original discs)	....	—	0.19	0.17	0.36
No infiltration	Normal	26	.93	.61	1.54
Infiltration with:					
Water	Normal	22	.88	.79	1.67
10^{-3} M iodoacetate, pH 5.5	Normal	21	.98	.63	1.61
5 x 10^{-4} M arsenite, pH 6.0	Normal	20	.92	.82	1.74
10^{-2} M NaF, pH 6.0	Injured	24	.92	1.30	2.22
10^{-5} M DNP[2], pH	Normal	24	0.54	1.72	2.26

[1]Means of 3 replications calculated as per cent of original fresh weight; L.S.D. (5%) = .23.
[2]2,4-dinitrophenol.

TABLE 4.—*Sugars in and appearance of Russet Burbank potato discs infiltrated with different concentrations of 2,4-dinitrophenol (DNP) at pH 5.0 or water and partially desiccated for 68 hours at 70° F.*[1]

Disc Treatment	Appearance after 68 Hours	Weight Loss	Reducing Sugars	Sucrose	Total Sugars
		Per cent	Per cent	Per cent	Per cent
None (original discs)	....	.....	0.17	0.05	0.22
Infiltration with:					
10^{-3} M DNP	Dead	26	.21	.05	.26
5 x 10^{-4} M DNP	Injured	25	.22	.59	.81
10^{-4} M DNP	Injured	25	.26	.66	.92
5 x 10^{-5} M DNP	Normal	24	.59	1.56	2.15
10^{-5} M DNP	Normal	25	.86	1.29	2.15
5 x 10^{-6} M DNP	Normal	25	1.00	1.12	2.12
Water	Normal	26	1.07	0.62	1.69

[1]Means of 3 replications calculated as per cent of original fresh weight.

subjected to similar partial desiccation, but the accumulated sucrose was increased enough so that more total sugars accumulated. The chief difference after partial desiccation between potato discs infiltrated with 5 x 10^{-6} M DNP, pH 5.0, and water was a greater amount of sucrose in the former. It is apparent from the data that as the concentration of DNP is increased smaller amounts of reducing sugars are accumulated. The pattern of accumulation at the different concentrations of DNP would seem to indicate that the reducing sugars arise from sucrose, at least in partially desiccated potato discs.

Sugar accumulation and respiration in potato discs during partial desiccation were investigated by comparing the effects of several metabolic inhibitors on the two processes. As shown in Table 5 the inhibitors DNP, NaF and to a lesser extent, KCN, have somewhat similar effects on sugar accumulation regardless of their differences in mechanism of inhibition (2). It would appear that moderate concentrations of metabolic inhibitors up to the point of disorganization and death of the tissue resulted in an increase in sucrose accumulation during partial desiccation. This is apparently equally true whether the rate of respiration was stimulated as by 10^{-4} M DNP or inhibited as by 10^{-2} M NaF, pH 6.0. Severe inhibition of respiration or energy transfer as by the treatment with 10^{-2} M NaF, pH 3.8, and 10^{-3} M DNP resulted in no sugar accumulation and the death of the tissue during 48 hours of partial desiccation.

Discussion

The results reported herein confirm the beliefs of earlier workers (5, 6) that sucrose is the product of starch hydrolysis *in vivo*. Sucrose is the only sugar to accumulate in potato discs during rapid desiccation or during slow desiccation after previous treatment with high to intermediate concentration of metabolic inhibitors. The results also indicate that during partial desiccation of potato discs reducing sugars arise from sucrose. This was shown by experiments in which potato discs were treated with successively weaker concentrations of metabolic inhibitors. As the concentrations of metabolic inhibitors were decreased larger amounts of reducing sugars accumulated and there was a closely corresponding decrease in sucrose accumulation. A similar pattern of accumulation was shown when the rates of desiccation were decreased. When the rate of desiccation was rapid only sucrose accumulated and when it was very slow only reducing sugars accumulated. It would appear that the more nearly normal metabolism of potato discs was during the period of partial desiccation the greater was the accumulation of reducing sugars.

There are at least two phases to the problem of sugar accumulation in potato tissue. The first phase concerns the biochemical pathway by which sucrose is synthesized from starch. This phase, which is enzymatic in nature, should presumably be inhibited by metabolic inhibitors. The present work shows that the biochemical synthesis of sucrose is less affected by low levels of oxygen and metabolic inhibitors than are other physiological processes such as sprouting. A similar conclusion can be reached from the fact that potato tubers accumulate the largest amount of sugars during storage at 31° F., a temperature at which most synthetic reactions are at a minimum. From these considerations it can be concluded that the biochemical synthesis of sucrose is fundamental in potato cell

TABLE 5.—*Sugars in and respiration of Katahdin potato discs infiltrated with different concentrations of certain metabolic inhibitors or water and partially desiccated at different rates at 70° F.*[1]

Rate of Desiccation and Disc Treatment	Weight Loss	Reducing Sugars	Sucrose	Total Sugars	Oxygen Uptake
	Per cent	Per cent	Per cent	Per cent	QO_2(FW)[2]
None (Original discs)	----	0.15	0.13	0.28	62
Rapid desiccation for 8 hrs. + infiltration with:					
Water	52	.17	.64	.81	68
10^{-2} M NaF, pH 3.8	56	.13	.21	.34	32
10^{-2} M NaF, pH 6.0	51	.15	.76	.91	61
10^{-3} M DNP,[3] pH 5.0	62	.17	.14	.31	67
10^{-4} M DNP,[3] pH 5.0	52	.22	.86	1.08	97
10^{-3} M KCN, pH 6.0	50	.20	.79	.99	54
10^{-4} M KCN, pH 6.0	54	.24	.68	.92	66
Slow desiccation for 24 hrs. + infiltration with:					
Water	11	.34	.41	.75	87
10^{-2} M NaF, pH 3.8	14	.15	.19	.34	35
10^{-2} M NaF, pH 6.0	12	.29	.80	1.09	60
10^{-3} M DNP,[3] pH 5.0	17	.16	.18	.34	58
10^{-4} M DNP,[3] pH 5.0	16	.24	.91	1.15	88
10^{-3} M KCN, pH 6.0	14	.27	.88	1.15	67
10^{-4} M KCN, pH 6.0	14	.31	.38	.69	85
Slow desiccation for 48 hrs. + infiltration with:					
Water	21	.58	.64	1.22	78
10^{-2} M NaF, pH 3.8	....[4]	.15	.20	.35	....[4]
10^{-2} M NaF, pH 6.0	24	.42	.91	1.33	72
10^{-3} M DNP,[3] pH 5.0	....[4]	.15	.15	.30	....[4]
10^{-4} M DNP,[3] pH 5.0	20	.36	1.12	1.48	86
10^{-3} M KCN, pH 6.0	24	.46	.92	1.38	85
10^{-4} M KCN, pH 6.0	21	0.57	0.73	1.30	95

[1] Means of 3 replications calculated as per cent of original fresh weight.
[2] Microliters of oxygen uptake at 70° F. per gram of original fresh weight.
[3] 2,4-dinitrophenol.
[4] Killed.

metabolism and that the process has a high priority in drawing upon available respiratory energy. Because of the fundamental nature of sucrose synthesis, it appears improbable that this process can be prevented by chemical treatments or conditions that do not lead to the death of the tissue.

The second phase of the problem concerns the causes of sugar accumulation. At present it is not known why sugars accumulate, but the partial blocking of the normal pathways of carbon utilization such as respiration and protein synthesis does not seem an adequate explanation. The fact that sugars accumulate in potato tissue under conditions of low and high temperatures and desiccation suggests that sugar accumulation may be a normal response to physiological stress. This relation between sugar accumulation and physiological stress could account, in part, for the findings that moderate concentrations of metabolic inhibitors increased

rather than decreased the amount of sugars accumulated during partial desiccation.

The possibility that the resistance of potato cells to physiological stress can be increased by chemical treatments remains to be tested. A more practical approach to the control of sugar accumulation in potato tubers would appear to be the selection of varieties resistant to sugar accumulation during low-temperature storage. This is especially true in view of the success of plant breeders in dealing with problems of frost, heat and drought resistance with which sucrose accumulation in the potato tuber appears to be related.

Summary and Conclusions

Sugar accumulation was studied in potato discs subjected to partial desiccation. Little or no sugar accumulated and no change in alcohol-insoluble solids was detectable when potato discs were partially desiccated in the absence of oxygen. In rapidly desiccated potato discs there was a limited accumulation of only sucrose. In slowly desiccated discs there was a large accumulation of both reducing sugars and sucrose.

Potato discs treated with metabolic inhibitors (iodoacetate, arsenite, fluoride and dinitrophenol) at intermediate concentrations accumulated sugars. Sucrose and total sugars were significantly greater in discs given fluoride and dinitrophenol treatments than in water-infiltrated control discs subjected to similar partial desiccation. In potato discs infiltrated with high concentrations of dinitrophenol sugar did not accumulate and the tissue was killed during partial desiccation. When only a part of the cells were killed only limited amounts of sucrose accumulated. It would appear that moderate concentrations of metabolic inhibitors up to the point of disorganization and death of the tissue resulted in an increase in sucrose accumulation during partial desiccation. This response was largely independent of the rate of respiration of the discs treated with the metabolic inhibitors. The results show that sucrose is the first sugar to accumulate from the *in vivo* hydrolysis of starch. There is evidence that reducing sugars arise from sucrose in potato discs during partial desiccation.

It is concluded as improbable that sucrose synthesis in potato tubers can be prevented by chemical treatments or conditions that do not lead to the death of the tissue. Sucrose accumulation in potato tubers is apparently related to frost, heat and drought resistance and the most practical approach for control would seem to be the selection of varieties resistant to these factors.

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THE EFFECT OF POTASH FERTILIZATION UPON POTATO CHIPPING QUALITY IV. — SPECIFIC GRAVITY[1]

TOM EASTWOOD AND JAMES WATTS[2]

INTRODUCTION

The chip color data from this series of experiments were reported in a previous paper (2). Also, the methods employed were outlined previously (1). In this presentation, data on specific gravity changes in the potato tubers will be submitted. Also, a brief summation will be included on the effects of the treatments upon reducing sugar content of the tubers, chip taste, keeping quality of the tubers in curing storage, and keeping quality of the tubers in cool/cold storage.

EXPERIMENTAL RESULTS

1. 1951 Camp Potato Experiment

Specific gravity data were similar for the potatoes grown with both levels of muriate of potash, 120 and 160 pounds per acre.

However, the potato varieties did not all react in the same manner. As an illustration, the use of 160 pounds per acre of potash decreased the specific gravity for the variety Russet Rural as compared with the use of 120 pounds per acre, whereas the reverse occurred for the Katahdin variety.

2. 1952 Camp Potato Experiment

Increasing applications of muriate of potash decreased the specific gravity of the potatoes. The drop in specific gravity was of practical magnitude as the potash level was raised from 80 to 120 pounds per acre, whereas it was only of statistical significance as the potash level was further raised to 160 pounds per acre.

Several interactions developed between the potash supply and the other experimental variables. The potato varieties varied in their responses in specific gravity toward the several levels of potash. There was an over-all progressive trend toward reduced specific gravity for the varieties Russet Rural and White Rural as the amount of potash was progressively increased. This trend was not so precise for the Kennebec and Nixon seedling. However, in all cases the specific gravity of the potatoes receiving 160 pounds of potash per acre was lower than that of potatoes receiving 80 pounds per acre.

Specific gravity was also altered according to the relative proportion of N and K_2O in the fertilizer application. However, there was no general trend in either magnitude or in direction for this interaction. The levels (80, 120, and 160 pounds per acre) of potash in the fertilizer showed a greater decreasing effect upon the specific gravity of the tubers than did the nitrogen level (40, 80, and 120 pounds per acre.)

Despite the fact that the over-all values for specific gravity decreased

[1]Accepted for publication February 1, 1956.

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with increasing lengths of previous cold storage treatments, no interaction developed between potash level and cold storage.

3. 1952 Penn State Experiment

The use of sulfate of potash resulted in a higher specific gravity than did the application of muriate of potash. However, the difference varied according to the particular series of the potatoes under test; that is, according to the length of previous cold storage treatment. Although no significant interaction showed up between potash source and cold storage, a small difference in specific gravity occurred as a result of the potash source in the lot of potatoes which had received the 9 weeks of cold storage before the curing storage period, whereas noticeable differences developed in the lots receiving 0 and 18 weeks previous cold storage.

Although a significant interaction was lacking between potash source and nitrogen level, an interesting trend was noted. The sulfate of potash increased the specific gravity of the tubers more compared with the muriate of potash when 75 pounds per acre of N were applied than when 150 pounds per acre of N were used. The extra N application partly counteracted the effect of the sulfate of potash.

In this experiment the use of 225 pounds per acre of muriate of potash resulted in a higher specific gravity in the Katahdin variety than was produced by use of 150 pounds per acre.

4. 1953 New Jersey Experiment

The use of sulfate of potash increased the specific gravity of the potato tubers noticeably in comparison with the use of muriate of potash. This difference was 0.0032 or 0.7 per cent dry matter, which was of practical value.

No reliable interactions developed between potash source and farm, potato variety or irrigation. The varieties were Cobbler, Chippewa, and Katahdin.

5. 1954 New Jersey Experiment

The use of sulfate of potash increased the specific gravity of the tubers when compared with muriate of potash for the varieties Cobbler and Chippewa, whereas no difference of significance occurred for the variety Katahdin.

6. 1954 Penn State Experiment

The trend toward reduced specific gravity of the tubers with the increased use of potash, as the muriate salt, in the range of 80-160-0, 80-160-80, 80-160-160, and 80-160-240 of N, P_2O_5 and K_2O pounds per acre, was influenced greatly by interactions with other variables. Low rates of potash, when using KCl, in the test produced higher values for specific gravity.

The interaction between farm location and potash level was mostly a matter of location, as this factor caused much greater differences. The specific gravity of the Katahdin was depressed more than was the specific gravity of the variety Russet Rural from the use of increased quantities of muriate of potash. Even here the cool/cold storage treatment altered both the influence of the potato variety and the effect of the level of potash on the specific gravity of the potato tubers.

The use of the sulfate of potash produced a general over-all greater specific gravity in the tubers than did the use of muriate of potash.

The effect of the source of potash upon specific gravity of the tubers was complicated by the presence of several interactions; namely, with farm location, previous cool/cold storage, and potato variety, including Katahdin, Kennebec, and Russet Rural. In this case the sulfate of potash caused a much greater increase in specific gravity compared with the muriate of potash with the variety Russet Rural than with the variety Katahdin.

Discussion and Summary

1. The use of increasing amounts of muriate of potash, in general, caused a decrease in specific gravity of the tubers.

2. Several interactions occurred between potash level and the other experimental variables: (a) The potash level response on the specific gravity varied with variety of potatoes. In some instances additional potash decreased the specific gravity of Katahdin and increased it for Russet Rural, and in other cases the reverse trend was found; (b) significant interactions were noted between nitrogen level and potash level, but the direction and the magnitude were erratic; (c) farm location developed a weak statistical interaction with potash level, whereas its own direct effect upon specific gravity was greater than that for the potash level; (d) a trend toward greater reduction in specific gravity in the tubers occurred when the higher amounts of potash were applied as the muriate than when applied as the sulfate of potash; and (e) weather conditions were a major factor in effecting specific gravity.

3. In general the use of sulfate of potash increased the specific gravity of the potato tubers in comparison with that produced by the use of muriate of potash.

4. Variable interactions were observed between potash source and the other experimental variables (a) the potato variety did not always react with potash source to alter the specific gravity of the tubers, other factors such as weather and cultural conditions caused further variability; (b) specific gravity was effected by a complex of factors including potato variety, potash level, and potash source; (c) potash source and irrigation did not interact in relation to specific gravity of the tubers; (d) the interrelationship between potash source and farm location was not consistent, with farm location causing a greater effect than did potash source; (e) an interesting trend was noted between potash source and nitrogen level; and (f) variable interactions developed between potash source and the cold storage treatments.

5. None of the potash variables had any definite influence upon the amount of reducing sugar in the potato tubers. Also, no practical interactions occurred between the potash variables and the other experimental variables such as potato variety, nitrogen level, irrigation, farm location, and length of previous cold storage treatments.

6. The potash variables, level and source, did not alter the quantity of losses of the tubers in curing storage. Likewise, no interactions developed between potash level and source and the other experimental variables such as potato variety, nitrogen level, irrigation, farm location and length of previous cold storage treatments.

7. The potash variables, level and source, had no effect upon losses under conditions of cool/cold storage. Also, no interactions developed between the potash variables and the other experimental variables, such as nitrogen level, potato variety, and farm location.

8. The potash variables, level and source, had no influence upon chip flavor. Evidence for interactions between the potash variables with the other experimental variables, such as nitrogen level, potato variety, irrigation and farm location, were not present.

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WASHING MUDDY POTATOES[1]

PAUL E. WAGGONER[2]

When potatoes are harvested late because of wet weather, they are apt to be muddy and cold when stored. Unless ventilation is ample, they do not dry readily in storage. Consequently, when marketed they are unsightly and frequently decay due to lenticel and wound infection. Their appearance can be improved by washing. The present experiments were designed to determine whether this washing 1) increased decay in potatoes already infected or 2) caused infection of potatoes wounded during the operation. Means of controlling decay were tested.

MATERIALS AND METHODS

Katahdin tubers that were covered with wet mud and rotten debris were obtained from a storage in December. After passing through a brusher and being graded for U.S. No. 1, they were placed in polyethylene bags for 3 days at 60-70° F. Twenty-eight per cent of the 370 tubers remained sound, 69 per cent decayed because of bacterial infection of lenticels, and 3 per cent decayed due to bacterial and fungal infection of wounds. Sound Katahdin tubers were obtained. They were dry and did not show any decay after 7 days at 65° in a polyethylene bag. Each experimental lot consisted of 5 pounds of the muddy tubers and 5 pounds of cut, sound tubers mixed together.

Unwashed lots were placed in net onion bags or polyethylene bags that had for ventilation 6 slits 1 inch long. Other lots were washed by tumbling the tubers together in 2-25 gallon tanks of water. Fresh water was used for each 10-10 lb. lots. The tubers were drained before bagging. Some of the washed tubers were then sprayed with 100 ppm. streptomycin from Agrimycin 100. Streptomycin prevents the inoculation of cut seed with certain decay bacteria (1). Some of the washed tubers were sprayed with 1000 ppm sorbic acid (2) furnished by Union Carbide and Carbon Corporation. This concentration of sorbic acid had prevented the growth of *E. carotovora*, soft rot bacteria, in nutrient broth.

Following washing and treatment, the bagged tubers were incubated 6 days at 65°. Then the infected, muddy tubers were inspected for bacterial decay. The cut, sound tubers were also inspected. This experiment of 5 replicates was followed a month later by another one of 5 replicates. In the two experiments a total of 2,961 tubers was inspected.

RESULTS

The tubers in the net bags became dry whereas those in the polyethylene dried somewhat but remained damp. The percentages of the tubers that decayed and the 95 per cent confidence intervals (4) are tabulated in table 1.

Many of the muddy, infected tubers rotted during storage. Both washing and drying decreased the number that rotted. Both streptomycin

[1]Accepted for publication April 4, 1956.
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TABLE 1.—*Per cent and 95 per cent confidence intervals of soft rot.*

Tubers	Treatment	Damp		Dry	
		Per cent Rot	Confidence Interval	Per cent Rot	Confidence Interval
Infected	Unwashed	52	43-60	11	6-18
	Washed	28	20-37	15	10-23
	Strep.*	16	9-24	7	3-13
	Sorbic*	18	11-27	4	1-9
Sound, cut	Unwashed	31	24-39	10	6-16
	Washed	10	7-15	2	1-5
	Strep.	11	7-16	1	0-4
	Sorbic	9	6-13	1	0-4

*Tubers were sprayed with 100 ppm streptomycin or 1000 ppm sorbic acid after washing.

and sorbic acid caused small, non-significant decreases in decay of either dry or damp, infected tubers.

About 1/3 of the cut, sound tubers became infected when they were mixed with the muddy, infected ones. Both washing and drying decreased the number that were infected and decayed. Any decreases caused by streptomycin or sorbic acid were non-significant.

Discussion and Summary

The results of these experiments are in essential agreement with Ruehle's (3): (1) washing didn't increase the decay of infected, muddy potatoes or the spread of infection; (2) drying was of paramount importance in controlling decay and spread of infection; and (3) disinfectants had little effect.

In these experiments washing not only did not increase decay, it decreased decay. This result probably depended upon the condition of the infected potatoes: they were covered with infested mud which spread to any sound, wounded tubers. Therefore, washing did not wet the tubers — which were already wet with mud — but may have hastened the drying by thinning out the layer of mud.

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THREE VIRUS COMPONENTS OF "INTERVEINAL MOSAIC" — IRISH COBBLER POTATO[1]

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Interveinal mosaic, a virus disease of the Irish Cobbler potato variety, was described by Schultz and Folsom in 1923 (10), Schultz in 1951 (9), and MacLachlan, Larson, and Walker in 1954 (6). The present studies have revealed the presence of potato viruses S and X in all Irish Cobbler material used, whether "healthy" or affected with "interveinal mosaic". It was confirmed that our source of the virus X-immune potato Seedling 41956, a host used in these studies to eliminate virus X, was infected with virus S. This was originally established in 1954 by R. H. Larson and D. H. M. van Slogteren (8). It was also ascertained that Irish Cobbler and Seedling 41956 used, did not contain known strains of potato viruses A, F, or Y, thus distinguishing "interveinal mosaic" of Irish Cobbler, respectively from: the "mild mosaic" of Schultz and Folsom (10), or "crinkle mosaic" of Murphy and McKay (7); the "interveinal mosaic" of Loughnane and Clinch (5); and the "rugose mosaic" of Schultz and Folsom (10). However, MacLachlan, Larson and Walker (6) had demonstrated that a factor was transmitted by grafting from "interveinal mosaic" Irish Cobbler to Seedling 41956 without inducing symptoms on the latter, and thence by further grafting, from Seedling 41956 to plants of *Datura tatula* (L.) Torr., where it caused systemic ring-like lesions after 21 days (6).

In the present study it was found that some factors in sap from "interveinal mosaic" Seedling 41956 caused local lesions, also ring-like in appearance (8-12 days) on certain species of *Datura*, notably *D. Bernhardii* Lund., and reddish local lesions on cowpea, *Vigna sinensis* Endl., var. Black, (14-21 days). Sap from "healthy" material of Seedling 41956 carrying only virus S caused no such lesions on cowpea or any species of *Datura* tested.

Mechanical inoculations with sap from Seedling 41956 which carried virus S, resulted in local necrotic lesions (6-12 days) on guar (*Cyanopsis tetragonoloba* (L.) Taub. (12); no local symptoms, but a well-defined systemic veinclearing followed by a chlorotic mottle (20-25 days), on *Nicotiana debneyi* Domin.; and local yellow spots (20-25 days) on *Chenopodium album* L. Rubbing with sap from "interveinal mosaic" Seedling 41956 resulted in very similar symptoms on the latter three hosts, except that the lesions on guar appeared earlier (4-6 days), and irregular brownish ring-like local lesions preceded the veinclearing on *N. debneyi*.

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[1]Accepted for publication April 18, 1956.
This investigation, conducted in the Department of Plant Pathology, University of Wisconsin, Madison, Wisconsin, was supported in part by a grant from the Research Committee of the Graduate School from funds supplied by the Wisconsin Alumni Research Foundation. Joint contribution from the Horticultural Crops Research Branch, Agricultural Research Service, U.S.D.A., University of Wisconsin, and the Botany and Plant Pathology Division, Science Service, Canada Department of Agriculture, Ottawa, Ontario, Canada. Contribution No. 1532.
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In a search for a host which might separate the "interveinal mosaic" factor from virus S, leaves of *Datura metel* L. from several sources, were rubbed with sap from "interveinal mosaic" Seedling 41956. Plants of one of these *D. metel* sources developed local necrotic lesions, followed by a systemic yellow spotting, and finally by an acropetal leaf-drop which resulted in the death of the plant.

Sap from upper leaves of *D. metel* showing the systemic symptoms described above, was rubbed on a young potato seedling grown from true seed. After thirty days, sap from this potato seedling was rubbed on leaves of a number of hosts. The first passage through *D. metel* had eliminated some part of the virus complex contained in the original "interveinal mosaic" Seedling 41956. *D. metel* now reacted with chlorotic local lesions and systemic spotting, but the lethal effect was lacking. *N. debneyi* reacted with the irregular brownish ring-like local lesions, without systemic symptoms. Local lesions appeared on guar (4-6 days) and on cowpea (14-21 days). No symptoms were produced on *C. album*. The above symptom reactions suggested that virus S was absent from this inoculum, leaving the "interveinal mosaic" factor.

An antiserum produced by intravenous injections of a rabbit with clarified sap from the above-mentioned potato seedling clearly distinguished between potato plants carrying the "interveinal mosaic" factor, and those not containing the factor, whether or not other viruses were present. This factor was given the code name "potato virus M."

Virus S and virus M appeared to have some serological component in common, but this represented a relatively small fraction of the antigenic activities of the respective viruses. The two viruses could be distinguished readily when the M and S antisera were diluted. Antiserum titres against the homologous viruses were 1/1600 for virus S antiserum and 1/2400 for virus M antiserum. The respective titres against the heterologous viruses were 1/20 and 1/40.

Using for identification and recovery purposes, the antiserum specific to virus M, and another specific to virus S, as well as the host plants *D. metel*, guar, and *N. debneyi*, a preliminary study was made of the host range of viruses M and S. Plants of tomato and eggplant inoculated with the two viruses from "interveinal mosaic" Seedling 41956 but showing no apparent symptoms, were found to carry only virus M, whereas virus S did not become systemic in these hosts. On the other hand, *Physalis Philadelphica* Lam. was a systemic host of virus S, but not of virus M.

It is significant in view of recent work in Europe (1, 3, 4, 11) describing viruses in the potato varieties Fortuna and King Edward, that sap extracts from these varieties reacted specifically with both the M and S antisera. It will be of interest to determine whether each of these two potato varieties contains separate virus components or a single virus which is antigenically related to both the M and S viruses.

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POTATO FUNGICIDAL SPRAY TRIALS IN WEST VIRGINIA, 1950-1955 RESULTS[1]

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Early blight (*Alternaria solani* (Ell. & Martin) Jones and Grout) and late blight (*Phytophthora infestans* (Mont.) D. By.) are important diseases of potato in West Virginia. Late blight, although sporadic, is usually more destructive than early blight. However, since early blight is usually present every year it often assumes a major role. In recent years many new fungicides have been developed for use in control of these diseases. Since the environmental conditions of the mountainous areas of West Virginia are characterized by high rainfall and persistent fogs and dews, it is necessary that new fungicides be tested here to determine their value under these conditions.

This paper reports the results of 5 years of fungicidal spray trials carried out over a 6-year period, 1950-1955. No tests were made in 1954. Previously, Vaughn and Leach (3) have reported comparisons of Dithane and several unnamed experimental copper fungicides with Bordeaux mixture for the control of potato defoliation diseases in West Virginia.

MATERIALS AND METHODS

The potato varieties Cobbler and Kennebec were sprayed in 1950 and 1951, Katahdin in 1952, and Pontiac in 1953 and 1955. During the first week in May, the seed-pieces were planted 10 inches apart in rows 3 feet wide and 20 feet long with a two-row picker-planter which deposited approximately one ton per acre of 5-10-10 fertilizer in bands along the rows. Each treatment was randomized and replicated 5 times; a treatment replicate consisted of a block of 4 or 6 rows surrounded by alleys 6 feet wide. The plots were located in the Tygart Valley (elevation 2200 ft.) near Huttonsville, West Virginia.

The fungicides were applied 6 to 8 times at weekly intervals beginning about the middle of June. Prior to the first applications of the fungicides, the plants were sprayed twice with DDT alone to control flea beetles. The spray mixtures were applied with a three-nozzle (size 3) hand boom at the approximate rate of 150 gallons per acre. Approximately 150 pounds pressure were provided by either a John Bean (Spartan) or Hanson (PTO) pump.

The plants in each plot were examined twice during each season for percentage defoliation by the method suggested by Horsfall and Barratt (2). After maturity, the tubers were harvested and graded; both the total weights and weights of grade U. S. No. 1 per plot were converted to bushels per acre. The defoliation percentages and yields were subjected to analysis of variance.

The fungicides zineb (65 per cent w. p.), maneb (70 per cent w. p.),

[1]Accepted for publication April 20, 1956.
Published with the approval of the Director of the West Virginia Agricultural Experiment Station as Scientific Paper No. 526, Morgantown, W. Va.

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nabam (19 per cent liquid), ziram (76 per cent w. p.), and Copper A (45 per cent Cu. w. p.) were supplied by E. I. du Pont de Nemours, Wilmington, Delaware; Tri-Basic Copper Sulfate (53 per cent Cu. w. p.) and Cop-O-Zinc (42 per cent Cu and 11 per cent Zn w. p.) were supplied by the Tennessee Corporation, College Park, Georgia; Yellow Cuprocide (90 per cent cuprous oxide w. p.) and zineb (65 per cent w. p.) by Rohm and Haas Company, Philadelphia, Pennsylvania; Calumet Copper Oxide (75 per cent Cu. w. p.) and Calumet Norblo Oxide (75 per cent Cu w. p.) by Calumet and Hecla, Inc., Calumet, Michigan; Copper MBT (concentration unknown) by Monsanto Chemical Co., St. Louis; Vancide 51ZW (50 per cent w. p.) by R. T. Vanderbilt Co., New York; Robertson's Copper (90 per cent Cu w. p.) by H. H. Robertson Co., Pittsburgh, Pennsylvania; Mercupron (20 per cent copper resinate and 0.2 per cent phenyl mercury salicylate, liquid) by H. L. Woudhuysen and Associates, New York; captan (50 per cent w. p.) by California Spray-Chemical Corporation, Richmond, California; Fungicide "X" (liquid of unknown composition and concentration) by Chemical Formulators, Inc., Charleston, West Virginia; Crag 658 (32 per cent Cu, 18 per cent Zn, 9 per cent Cr. w. p.) and unnamed compounds (70 per cent w. p.) CC-1217, CC-7443, CC-7764, and CC-8739 were supplied by Carbide and Carbon Chemicals Company, New York.

The adjuvants used were Kaysoy 200 soya flour (Archer-Daniels-Midland Company, Minneapolis), Furafil 100 (Quaker Oats Company, Chicago), Granular Bentonite (Yodak Chemical Company, St. Louis), Good-Rite p.e.p.s. (B. F. Goodrich Chemical Company, Cleveland), Nutri-Leaf and VHPF soluble fertilizers (Miller Chemical and Fertilizer Corporation, Baltimore). Zinc sulfate monohydrate was used in tank reactions with nabam and Fungicide "X."

DDT was used as the standard insecticide in all spray mixtures at the rate of 1 pound of active ingredient per 100 gallons. In addition, malathion (½ lb. of active ingredient) was used for aphid control when needed.

Experimental Results

Results in 1950.—The 1950 growing season was extremely wet and cool and late blight was quite severe. Rapid development of late blight masked defoliation by early blight on the variety Cobbler. Early blight was present and was responsible for some defoliation on the late blight resistant Kennebec variety. Late blight became the dominant disease on Kennebec when physiologic potato race 1.4 of *P. infestans* appeared. Of the 19 different fungicidal treatments used on Cobbler, best late blight control and highest yields were obtained from the use of zineb alone (Table 1). Except for Copper MBT and Crag 658, the copper fungicides gave adequate control. However, best results were obtained with Bordeaux mixture and Yellow Cuprocide. When either Calumet Copper Oxide or Tri-Basic were alternated with zineb, yields were almost as high as those obtained with zineb alone, even though defoliation control was not as good 96 days after planting. Although defoliation control with Calumet Copper Oxide alone was equal to that obtained with the other copper fungicides, the yield was lower. However, the yields were increased when either the soluble fertilizer VHPF or zinc sulfate and lime were mixed in the spray tank with Calumet Copper

TABLE 1.—*Late blight defoliation and yield of Cobbler potatoes in 1950 when sprayed with different fungicides.*

Fungicidal Treatment	Concentration Pounds/Gallons	Per cent Defoliation Days after Planting		Yield Bushels/Acre	
		88	96	Total	No. 1
Zineb	3-100	8.3	22.9	410	369
Yellow Cuprocide	4-100[1]	9.0	37.9	358	328
Bordeaux Mixture	8-4-100	8.4	28.2	350	313
Copper A	4-100	11.7	45.2	347	306
Tri-Basic Copper Sulfate	4-100	10.2	38.7	335	299
Cop-O-Zinc	4-100	11.0	40.9	333	297
Nabam + $ZNSO_4$ + Lime	2 qt.-1-½-100	37.7	88.6	335	292
Copper Oxide, Calumet	3-100	8.8	43.4	322	286
Copper MBT	3-100	23.6	81.5	320	283
Crag 658	2-100	11.9	58.8	313	268
Zineb and Copper Oxide — alternating	3-100, 3-100	7.1	34.5	402	361
Copper Oxide + VHPF[2]	3-6-100	10.5	52.6	385	346
Zineb and Tri-Basic — alternating	3-100, 4-100	8.8	50.5	369	332
Ziram + Copper Oxide — tank mix	2-1½-100	10.4	54.6	378	330
Ziram, then Tri-Basic[3]	2½-100, 4-100	10.7	36.1	368	328
Ziram + Tri-Basic — tank mix	2-2-100	11.9	39.4	371	326
Copper Oxide + $ZnSO_4$ + Lime	3-1-1½-100	9.4	41.9	356	315
Ziram, then Copper Oxide[3]	2½-100, 3-100	14.2	49.8	306	277
Control (DDT alone)	———	99.9	100.0	276	234
LSD	19:1	6.9	12.6	48.4	46.1
	99:1	9.1	16.8	64.1	61.4

[1]By mistake the concentration of Yellow Cuprocide was twice that recommended.
[2]VHPF used with Copper Oxide in last two applications.
[3]Ziram alone was used in the first two applications followed by the copper fungicides in last 6 applications.

Oxide. Yields were higher when ziram was used in tank mixtures with either Tri-Basic or Copper Oxide than when the copper fungicides were used alone. When ziram was used in place of the first two applications of the Tri-Basic copper, there was an increase in yields which did not result when ziram was substituted in the first two spray treatments of the copper oxide plots.

The advantages of spraying the late blight resistant Kennebec variety are illustrated by the data in table 2. Little late blight was found on plants sprayed with either zineb, Tri-Basic, or Bordeaux mixture. The plants receiving no fungicide were almost completely defoliated by late blight. Potato physiologic race 1,4 of the late blight fungus appeared on Kennebec plants two weeks after race 0 was observed on near-by Cobbler plants; it spread rapidly and masked the effects of early blight. Best control of the diseases and highest yields were obtained with zineb.

Results in 1951.—In 1951 the early part of the growing season was cool and wet, whereas the latter part was warm and dry. Although

TABLE 2.—*Defoliation resulting from both early and late blight, and yield of Kennebec potatoes, in 1950 when sprayed with different fungicides.*

Fungicidal Treatment	Concentration Pounds/Gallons	Per cent Defoliation Days after Planting		Yield Bushels/Acre	
		101	111	Total	No. 1
Zineb	3-100	2.2	18.0	567	499
Tri-Basic	4-100	2.5	31.9	521	466
Bordeaux Mixture	8-4-100	2.4	26.5	521	457
Control (DDT alone)	——	33.3	97.0	396	335
LSD	19:1	13.9	12.6	54.1	42.6
	99:1	20.0	18.7	77.8	61.3

late blight was present, it was of minor importance, with early blight causing most of the defoliation. The differences in yield (Table 3) were not significant. The best fungicides for early blight control were maneb, nabam + zinc sulfate, Bordeaux mixture and zineb. Crag 658 and CC-1217 gave poor control. There was little difference between the performance of Tri-Basic and Calumet Copper Oxide. The use of the adjuvants bentonite, Nutri-Leaf, and p.e.p.s. failed to improve the performance of the copper oxide fungicide.

Results in 1952.—The 1952 growing season was hot and dry except for the very early part. Early blight was the most serious and destructive disease; late blight was present but of little importance. The differences

TABLE 3.—*Defoliation by early blight and yield of Cobbler potatoes in 1951 when sprayed with different fungicides.*

Fungicidal Treatment	Concentration Pounds/Gallons	Per cent Defoliation Days after Planting		Yield Bushels per Acre	
		97	105	Total	No. 1
Maneb	2-100	12.4	27.5	328	257
Tri-Basic Copper Sulfate	4-100	22.2	50.9	292	235
Nabam + Zn SO_4	2 qt-¾-100	12.9	34.9	286	228
CC-1217	7-100	26.0	64.0	273	221
Bordeaux Mixture	8-4-100	19.0	36.0	268	210
Zineb	2-100	17.1	41.0	252	208
Zineb	3-100	16.0	37.5	259	206
Zineb + Nutri-Leaf	3-6-100	16.9	32.1	269	235
Zineb and Tribasic — alternating	2-100, 4-100	15.3	45.0	286	207
Copper Oxide, Calumet	3-100	18.7	44.5	260	206
Copper Oxide + Bentonite	3-½-100	17.5	42.6	308	250
Copper Oxide + p.e.p.s.	3-½-100	16.7	40.2	271	215
Copper Oxide + Nutri-Leaf	3-6-100	21.6	45.6	271	208
Crag 658	2-100	25.9	59.6	238	171
Control (DDT alone)	——	67.8	94.8	245	185
LSD	19:1	9.6	12.1	NS	NS
	99:1	12.9	16.2	NS	NS

in yield (Table 4) among treatments were non-significant even though there was a variation of approximately 75 bushels per acre between the highest and lowest yields. Maneb, zineb, and nabam plus zinc sulfate gave best control of defoliation due to early blight. A considerable amount of plant injury resulted from applications of the Bordeaux mixture which accounted for part of the defoliation on plants sprayed with this material. There was little difference between the performances of Tri-Basic, captan, Vancide 51ZW and Calumet Copper Oxide. The adjuvants Furafil, bentonite, and soya flour failed to improve the performance of Copper Oxide. Flea beetle and leafhopper damage was severe on plants sprayed with Mercupron and DDT indicating that this fungicide interfered with the insecticidal action of DDT.

TABLE 4.—*Early blight defoliation and yield of Katahdin potatoes in 1952 when sprayed with different fungicides.*

Fungicidal Treatment	Concentration Pounds/Gallons	Per cent Defoliation Days after Planting		Yield Bushels per Acre	
		98	113	Total	No. 1
Maneb	2-100	13.1	80.7	256	234
Zineb	2-100	14.7	85.3	242	222
Zineb	3-100	14.4	75.2	240	221
Zineb and Tribasic — alternating	2-100, 4-100	29.9	98.3	208	189
Bordeaux Mixture	8-4-100	30.2	92.4	239	216
Nabam + Zn SO_4	2 qt.-¾-100	17.8	89.7	224	206
Tribasic Copper Sulfate	4-100	29.5	95.0	227	205
Captan	3-100	25.7	98.4	223	204
Copper Oxide, Calumet	2.7-100	34.1	99.2	183	162
Copper Oxide + Furafil	2.7-1-100	23.7	97.7	223	200
Copper Oxide + Bentonite	2.7-1-100	27.7	98.4	208	185
Copper Oxide + Soya Flour	2.7-1-100	30.9	99.0	187	163
Vancide 51ZW	2-100	22.0	98.9	205	185
Mercupron	3-100	42.6	98.8	184	159
Control (DDT alone)	———	47.9	97.9	188	170
LSD	19:1	18.8	9.9	NS	NS
	99:1	NS	13.2	NS	NS

Results in 1953.—The 1953 growing season was similar to the seasons in 1951 and 1952. Pontiac, a late-maturing variety, was used for these trials in place of Cobbler and Katahdin used the previous three seasons. Defoliation resulted from both early blight and late blight (Table 5). Highest yields and best control of defoliation were obtained with maneb and zineb. There was little difference in performance between the 2 pound and 3 pound concentrations of zineb. The split schedule, in which zineb was used in the first 6 applications and Bordeaux mixture in the last two, gave results equal to those obtained with maneb or zineb alone. There was little difference in the performance of captan, Robertson's Copper, Calumet Norblo Oxide, and Tri-Basic. Norblo Oxide (a finely ground preparation of Calumet Copper Oxide) gave slightly better disease control and produced higher yields than Tri-Basic. In the three previous seasons when the regular preparation of Copper Oxide had been used, Tri-

TABLE 5.—*Defoliation resulting from both early and late blight, and yield of Pontiac potatoes in 1953 when sprayed with different fungicides.*

Fungicidal Treatment	Concentration Pounds/Gallons	Per cent Defoliation Days after Planting		Yield Bushels per Acre	
		103	110	Total	No. 1
Maneb	2-100	14.2	32.2	740	707
Zineb	2-100	18.5	39.5	703	651
Zineb	3-100	12.4	39.5	716	673
Zineb, then Bordeaux Mixture*	2-100, 8-4-100	12.4	32.0	734	705
Captan	2-100	32.3	84.2	642	614
Robertson's Copper	2.2-100	22.5	55.5	648	619
Norblo Oxide, Calumet	2.7-100	20.2	48.0	641	610
Tri-Basic Copper Sulfate	4-100	23.6	54.0	633	584
Bordeaux Mixture	8-4-100	40.3	70.9	520	487
Control (DDT & malathion, only)	———	60.7	94.6	620	582
LSD	19:1	9.8	16.4	78.3	77.9
	99:1	13.1	21.9	104.6	104.0

*Zineb used in first 6 applications and Bordeaux Mixture in last two.

Basic had given slightly better results. Bordeaux mixture caused some plant injury which resulted in yields lower than those of the controls.

Results in 1955.—Both early blight and late blight were present in the plots in 1955. Early blight was responsible for most of the defoliation. The growing season was warm with a moderate amount of rainfall. Experimental compounds Fungicide "X," CC-7443, CC-7764, and CC-8739 were included in the 1955 test for comparison with five named fungicides. The data in table 6 show that all materials prevented defoliation by early blight up to 100 days after planting; however, at 120 days after planting (past the time of normal maturity) only zineb, maneb, nabam plus zinc sulfate, and Fungicide "X" plus zinc sulfate provided significant control of defoliation. One hundred days after planting, the fungicides were grouped and arranged in order of decreasing efficiency of defoliation control as follows: 1) zineb, nabam plus zinc sulfate, maneb, and Fungicide "X" plus zinc sulfate; 2) CC-7764 and CC-8739; 3) Tri-Basic and Bordeaux mixture; 4) CC-7443; 5) control. Yields significantly higher than those of the control plots, in descending order, were provided by applications of zineb, nabam + $ZnSO_4$, maneb, Fungicide "X" + $ZnSO_4$, CC-7764, and CC-8739.

Discussion and Conclusions

Both late blight and early blight were present in the experimental spray plots each year. Late blight was severe in 1950, moderate in 1953 and of minor importance in 1951, 1952 and 1955. Early blight was moderate to severe each year except in 1950. Zineb and maneb consistently gave best control of defoliation caused by the two diseases and produced highest yields. This is in keeping with results obtained with these two materials by a number of other workers in other states (1). Except for the one year (1950) when late blight was severe and lime was used in

TABLE 6.—*Defoliation by early blight and yield of Pontiac potatoes in 1955 when sprayed with different fungicides.*

Fungicide	Concentration Pounds/Gallons	Per cent Defoliation Days after Planting		Yield Bushels per Acre	
		100	120	Total	No. 1
Zineb	2-100	4.0	74.5	741	673
Maneb	2-100	4.3	86.2	666	612
Nabam + Zn SO_4	2 qts.-¾-100	4.2	79.9	683	620
Fungicide "X" + Zn SO_4	2 qts.-¾-100	4.9	86.4	660	600
CC-7443	1½-100	12.5	98.2	594	540
CC-7764	1½-100	6.6	91.4	646	593
CC-8739	1½-100	6.6	96.3	641	592
Tri-Basic Copper Sulfate	4-100	8.6	98.4	584	541
Bordeaux Mixture	8-4-100	8.9	97.4	556	514
Control (DDT & malathion, only)	————	42.1	98.3	575	525
LSD	19:1	5.2	10.5	63.7	62.9
	99:1	7.0	14.0	85.0	84.0

the mixture, nabam plus zinc sulfate was about as effective as zineb. Only small differences were noted in performance of the different fixed Copper fungicides; Tri-Basic Copper Sulfate, Calumet Copper Oxide, Calumet Norblo Oxide, Cop-O-Zinc, Robertson's Copper, Copper A, and Yellow Cuprocide. Calumet Copper Oxide was slightly inferior to some of the copper materials, whereas Norblo Oxide (a preparation of Calumet Copper Oxide with smaller particle size) was slightly better than some. Bordeaux mixture gave good control of the two diseases but caused some injury to plants resulting in lowered yields. The performance of captan and Vancide 51ZW was inferior to that of zineb and maneb but was equal to that of the copper fungicides. Mercupron appeared to interfere with the action of the insecticide DDT and gave poor defoliation control and low yields. The performance of Calumet Copper Oxide was slightly improved in 1950 when the adjuvant VHPF was used in the spray mixture. This improvement could have been due to an increase in copper solubility brought about by the ammonium form of nitrogen present in the soluble fertilizer or to the supplementary fertility supplied by VHPF. The use of other adjuvants with Calumet Copper Oxide failed to improve its value as a fungicide. Various split schedule or tank mix formulations with zineb showed no advantage over the use of zineb alone. Unnamed experimental fungicides found to be worthy of further studies were Fungicide "X," CC-7764, and CC-8739.

It was found advantageous to spray the late blight resistant variety Kennebec for control of early and late blight. Best control of the two diseases on Kennebec and highest yields were obtained with zineb.

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NEWS AND REVIEWS

STORING WASHED POTATOES[1]

J. D. SWAN, JR.[2]

You honored me highly when you invited me to visit your great Field Day, which has given me an opportunity not only to mingle with your thousands of guests but also to speak to you this afternoon. Your committee asked me to choose my own subject and knowing your increasing interest in washing potatoes for better marketing, I have chosen the rather unconventional subject, "Storing Washed Potatoes."

INTRODUCTION

It is, of course, common practice today and most markets demand the washing of potatoes by the shipper. This is commonly done from the field or later from storage immediately before shipment. A good wash job and a "bright" pack command a premium. It is comparatively easy to get a clean bright wash job at time of harvest in the fall and shipments at that time can be a source of pride, even from heavy or dark soils. Many a grower has, however, put potatoes from such a field into storage, to take them out later to be washed for his winter trade, only to find that the tubers fail to brighten up because they have lost their "bloom."

About fifteen year ago, quite by accident, we discovered that by reversing the order and washing some potatoes *before* storage that they came out months later substantially as bright as when they went in. The subsequent development by trial and error and planning our system of management to first, washing and then storing them, have prompted quite some national interest and considerable correspondence from potato men.

DISCUSSION

Our potatoes in southern Wisconsin are grown on tiled muck soil. The fine dark soil clings tenaciously to the tubers and does not respond even to a good dry brushing job unless the potatoes are harvested from dry soil and the ambient dew-point temperature is well below the temperature of the potatoes at the time of brushing. The reverse of this condition is likely to prevail during late fall digging and the resulting pack is dirty and smeared with the dark soil. Late in the thirties we found we had to wash if we were to compete in the market with any chance for success. We found it easy to wash cleanly the freshly dug, and still damp potatoes as they were brought in from the field. This was satisfactory for immediate sales.

However, we found that our washing equipment was incapable of doing as clean a job late in the winter or early spring after the dirty potatoes had gone through the handling of binning, in addition to storage sweat and hardening. Furthermore, the skins, even when cleaned, were darker for they had lost their "bloom."

In the fall of 1940 we had washed a special pack order of two truck loads of large Katahdins and stacked them in burlap bags in the warehouse

[1]Accepted for publication August 1, 1956.
Paper presented July 26, 1956 at Potato Field Day, Potato City, Pa.
[2]Potato and vegetable grower, operator of Turtle Valley Farms, Delavan, Wis. and immediate past-pres. of Vegetable Growers' Assoc. of America.

for loading early the next morning. The buyer failed to appear. The market was very low that fall, and had recently slipped lower. It was evident our buyer had "welshed". Rather than risk a consignment we decided there was little to lose on an experiment and decided to dump the entire lot into a bin, even though we had always been told that washed potatoes "wouldn't keep."

Our potato storage was then of the conventional basement sectionalized design with bins approximately 8′ x 18′ x 8′ on raised slatted floors, depending upon gravity ventilation. The basement temperature at time of filling was approximately 55° F. and declined steadily to about 38° or 40° by January first where it remained until the lot of potatoes was removed late in February. At that time the potatoes were taken directly from the bin, run across a picking table and bagged. They were many shades brighter than could be obtained from conventionally stored identical lots. The yield of U.S. Number 1 potatoes was within a few bags of the number that was originally dumped in the bin some four months before. There was negligible decay, which was principally confined to shrivelled late blight lesions. There had been abnormal rain during the late summer of 1940 at which time there was a trace of tuber blight. To guard against the possible spread of tuber blight in the washing process we had suspended a cotton bag of tribasic copper sulfate in the channel of water pumped to the first battery of soaking sprayers on our washer, hoping to kill any free blight spores before they could damage uninfected tubers. The second section of our washer provided a separate battery of spayers using fresh clean well water as a final rinse on the conveyor. We have no comparative data for justification for the conclusion that the introduction of the copper accomplished its purpose other than the observation that no appreciable spread of blight followed in storage whether by coincidence or otherwise.

The agreeable anomaly, however, that resulted from the experiment was the brightness and "bloom" of these potatoes as they came from the bin in February closely rivalling the appearance of freshly washed autumn shipments.

Washes All Stored Potatoes

With the results of our experiments in mind, the following year we intentionally washed about one tenth of our storage crop before putting it into storage. The results were substantially the same. Each subsequent year we doubled the percentage so handled in the previous year until in 1946, and since that time we have washed our entire production before putting it into storage.

Some technical observations of some of the details of the management of our present operations may be of interest at this point. Some of our potatoes are picked up by hand behind the digger, and some times we use automatic harvesting and bulk-loading in self-unloading wagons. In either case, the potatoes from the field are unloaded on a wide rubber conveyor belt which empties on a roller conveyor to eliminate loose soil. From there they pass to a twenty foot roller washing-conveyor which gently turns the potatoes as they pass through and under the two batteries of sprayers First, there is a flushing or soaking unit which sprays, at the rate of approximately 3000 gallons per hour, re-circulated water freshened by the re-use of the water which is salvaged from the rinse unit nozzles

that are supplied by a 2500-gallon per hour well pump. Next, a blanket roller type of water eliminator follows the sizer and removes some of the free water after which the tubers enter the drying tunnel conveyor. This tunnel is forty feet long and during the two minutes the potatoes are in the tunnel they are exposed to a 5000 feet per minute air blast heated by a 6 gallon per hour oil burner This serves to raise the air temperature only enough to increase its moisture capacity and the drying action on the potatoes. The surface temperature of the potatoes rises only a very few degrees. Finally, the potatoes pass along the double lane culling or grading table and from there to the baggers or packaging machines as needed, or trucked to the bin loaders for storage At .this point the potatoes are not completely dry except on days of very low humidity, but no free water remains on the surface. Even though they may be damp, this dampness disappears in an hour or two in the bin or vented package. We think this dampness is beneficial in the initial stages of storage to aid in the healing of any cuts. By the aid of remote reading thermometers we keep the temperature as high as 60 degrees the first few days after storing the potatoes in the bins, and cool them as rapidly as possible with a minimum of forced air through the pile.

Avoids Bruising

Every effort is made to avoid tuber bruises at each point in the operation and no free fall exceeds a few inches to a padded surface.. We believe this to be a very important part in this system. Also, the stored potatoes must be mature enough not to feather during the process, as any spot where the skin is broken will darken in storage, and reduce the attractiveness of the pack. We do not consider the introduction of heat in the drying tunnel to be essential for storage where forced ventilation of the bin is available. Heat is merely desirable in reducing the requirement of forced bin blowing. Excessive blowing in the bin has tended to darken any abrased areas on a tuber. Most of our storage area is now provided with forced ventilation introduced through emptying conveyor passages and slatted bin bottoms at approximately ½ inch static pressure. The operation of blowers is controlled by time relay switches connected to safety thermostats. After the temperature of the stored tubers is reduced to 40 degrees, forced ventilation is reduced to a few minutes a day and a differential thermostat is cut in the control circuit which never permits the blowing of air that is warmer than the pile. Weight loss tends to the lower rates and is checked by dropping filled pre-weighted mesh bags into the heart of the bulk pile. After five months of storage we have had as little as 4 per cent, and as much as 10 per cent total shrinkage, during the past ten years of the evolution of this system.

The size of bin is apparently of no significance to keeping quality. Our largest bin holds fifty carloads without a partition; the smallest holds half a car. There is no appreciable difference in the out-turn quality of either, nor is the elaborate equipment used a necessary condition for the success of the system. (Ours is nearly all home-built and toggled up in our farm shop including the washing and drying line and conveyors.) They are merely conveniences we have added from time to time over a period of years.

The use of this system is, by no means, confined to muck soils. We also operate a seed potato farm on the heavier sandy loam of northern

Wisconsin. The larger sizes of tubers are washed and sold in table stock markets. Last fall, being a wet season, the potatoes came in muddy from the fields. We knew we would have difficulty cleaning them up in the spring, so we applied the principles of our washing-then-storage system to our simple washing-grading equipment located there. We permitted a drying action of sorts to take place by simply delaying the dumping of the tubers from the grader into the bins for a few hours, then dumping continuously from the drier lots in rotation. Although we had no forced ventilation the potatoes came out this spring to make U. S. Number 1 grade and were brighter than usual.

To date we have never had a serious loss from storage under this system and have applied it to a wide variety of potatoes including: Katahdins, Chippewas, Sebagoes, Russet Burbanks, Cobblers, Triumphs, LaSodas, Red Pontiacs and others.

The obvious disadvantage of the system is the requirement that the washer-grader must have a capacity equal to the rate of harvesting in the field for economic labor utilization and the use of relatively slightly more labor at harvest time to man the washer-grader than would be the case of hauling field-run potatoes and dumping them, dirt and all, directly into the bins for winter storage and subsequent washing and grading.

Advantages

It has been our experience and observation, however, that in our case and under our conditions these disadvantages are more than off-set by the advantages of much smaller winter labor requirements. First, to pack the already washed and rough-graded potatoes from the bins; secondly, the elimination of the problems and discomforts of washing and water handling in cold weather; thirdly, the saving of storage space by eliminating obvious culls at harvest time and above all the improved appearance and market quality of the finished pack that is offered in competition for the consumers' dollar.

Summary

In the normal process of binning freshly-dug unwashed potatoes the abrasive action of the tuber and the soil upon tubers while building up the storage pile apparently drives an appreciable amount of soil into the surface of the skin. The subsequent early storage sweat, or metabolic processes, appear to heal the dirt into the epidermis itself, and if the soil if of a darker shade subsequent winter washing fails to restore the original brightness of the tuber.

Fifteen years of experience without serious storage losses suggests that freshly dug and washed potatoes can be successfully stored under Wisconsin conditions if *mature* tubers are relatively free from 1, diseases; 2, bruises; and 3, free water at time of storing. The storage temperature the first few days should be relatively high, then dropped as rapidly as possible to, and maintained at the desired level, for the intended use and length of storage. Reasonably good ventilation seems to be required and controlled ventilation is desirable.

Even after prolonged storage, washed potatoes so stored have tended to pack out with brightness comparable to freshly dug and washed potatoes of the same lot in the fall of the year. Customer acceptance has been gratifying.

INFLUENCE OF ATMOSPHERIC AND SOIL MOISTURE CONDITIONS ON DIURNAL VARIATIONS IN RELATIVE TURGIDITY OF POTATO LEAVES

ABSTRACT OF NEBRASKA AGR. EXP. STA. RES. BULL. 176, DEC. 1954.

H. O. WERNER

Relative turgidity (R.T.) of potato leaves was determined with paired sets of leaf disks, one of which was used for dry matter determination while the other was floated on water to determine maximum water absorption capacity. First visual evidence of water shortage in leaves occurred when R.T. had dropped to about 82% but there was considerable difference between varieties. In the bright, dry atmosphere of western Nebraska (4000 ft. alt.) R.T. varied from maximum of 95 to 100% in early A.M. to minima of 82-86% in mid-P.M. Max. R. T. values were associated with atmospheric vapor deficit during the previous night or previous afternoon. The magnitude of the daily R.T. range was influenced chiefly by accumulative vapor deficit from sunrise to mid-afternoon (deficit measure with spherical black atmometers). R.T. values declined at a diminishing rate till midafternoon and then increased. The lag of R.T. increase in late P.M. and night, behind the increase in R.H. of atmosphere, was interpreted as due to water deficiency within the plant or the micro-root environment. When soil moisture in top 18 inches neared the wilting point max, and min. R.T. values decreased and daily range increased. In eastern Nebraska (Lincoln)—with temperatures much higher than in western Nebraska—max. A.M. R.T. values were never over 90% (except with overnight rain or irrigation) and min. were below 78%. When irrigated after a drouth period, plants had the appearance of recovery several days before R.T. of leaves was equal to that of leaves of plants irrigated continually. R.T. values of varieties differed very little when soil moisture was readily available but when moisture was deficient max. A.M. values differed more and minimum P.M. values differed greatly. Variety differences increased during protracted hot dry periods. R.T. values of Pawnee were consistently highest with least daily range, followed by Irish Cobbler, LaSoda, Red Warba and Progress. Those of Triumph were distinctly lowest with greatest range.

NEWS RELEASE

The eleventh annual meeting of the Northeastern Weed Control Conference will be held January 10, 11 and 12, 1957 in New York City at the Sheraton-McAlpin Hotel. An interesting program is being planned for those interested in weed control in such crops as corn, wheat, soybeans, pastures, vegetables, strawberries and orchards; for weed control in lawns, golf courses, nurseries, ponds and streams; and for control of woody plants and weeds along highways, railroads, power lines and around industrial plants.

Dr. L. L. Danielson, Plant Physiologist at the Virginia Truck Experiment Station, Norfolk, Virginia, is President of the Conference this year.

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